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Electricity generation development of Eastern Europe: A carbon technology management case study for Poland

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ABSTRACT

Energy and electricity in particular, are of unquestionable value for the welfare of all modern societies. The electricity sectors of Eastern European countries have undergone several phases of development between the post-WWII days within the CEMA and USSR frameworks and today's EU and global energy and environmental regimes. The present paper examines the progress of the Polish electricity sector throughout the last decades, providing useful information regarding not only the technical generation and distribution infrastructure but also the policies that have been and are currently implemented. The results are discussed in the context of indicators such as the electricity intensity and per capita consumption, and show that although the Polish electricity sector has gone a long way, there still are several necessary technology management steps to be taken if Poland is to adequately address the challenges of international competition, electricity supply security and environmental sustainability.

Contents

1. Introduction

Energy is one of the key factors for the well being of modern societies [1]. One may state that the desire to cover energy needs is expanding to such extend that it leads the foreign affairs agenda of countries from across the development spectrum [2]. As the dependence on energy grows, forms of energy with higher flexibility and user-friendly characteristics are becoming more popular. Electricity, being the best example of the described energy forms is facing increased demand in all sectors of the economy [3]. Hence, it is not only the households that use electricity to cover an increasing number of their energy needs but also the industrial sector where electric machinery is a substitute for old-fashioned thermal equipment [4]. Additionally in the transport sector the use of electric public and private vehicles is expanding as a way to abate urban pollution and traffic congestion, but furthermore electric trains are being used in long distance national and international routes [5]. Finally it is often the case that electricity is used more extensively despite the fact that it is not the most efficient form of energy and in several cases its use involves additional costs.

While the aforementioned observations are factual not only for the vast majority of developed but also for developing countries, they gain significant value in the European continent in large measure due to the European Union being the dominant political and financial player in the area. Within the EU there are significant efforts to create common policies regarding the electricity generation, transmission and retail [6]. Simultaneously the EU aspires to be recognised as the world leader in climate change abatement initiatives and air pollution measures [7]. Despite these

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efforts the 27 member states of the EU, coming from radically different regulatory and technical backgrounds follow their individual paths in order to comply with the EU legislation regarding both energy and environmental issues.

The EU-15 member states, or in other words the countries which have been EU members since before 2004 (prior to the EU integration of May 2004), although considered as developed economies, present a wide variety in the management of their energy and particularly their electricity sectors. Only slightly more unified is the situation with regard to environmental policy mainly due to the reduced need for capital intensive infrastructural investments. Nevertheless the ability of each member state to comply with the EU air pollution control directives is heavily dependent on factors such as the historical background, energy intensity, renewable and clean energy potential and the environmental awareness and consciousness of the public.

With 2004 being the landmark year for European Integration, the EU has proceeded in its largest expansion ever. Ten new countries have joined the union, increasing the number of its members to 25. Of the new-comers only Malta and Cyprus are not located on the continental Europe while the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia and Slovenia form the EU-8 with a common background regarding their location and the transitional nature of their economies. By the beginning of year 2007 the latter group has gained another two countries – Bulgaria and Romania – bringing the number of the EU states to 27. Exactly like the Western EU members, the Eastern EU states present a wide variety in their energy sectors as a result of the centrally planned economy of the USSR regime which determined some countries energy exporters and others energy importers, depending on their natural resources but also their industrial bases [8]. However, one may observe that significant common characteristics exist, namely the lack of pollution control measures and the inertia towards liberalisation efforts in the electricity sector. At the same time Eastern European states face similar obligations under the EU policies for the environment and the electricity generation and related difficulties to comply as a consequence of their transitional economies.

Within the Eastern European environment the EU states vary extensively in land area, population, gross domestic product, and primary and electricity consumption. In all these respects Poland is unarguably the largest country of the area as one may notice from Table 1 [9]. More specifically, Poland has the biggest population and area of all the Eastern EU countries, but it also presents almost the highest population density. Polish GDP is by far the highest in the region but still the GDP per capita is slightly short compared to the regional average of €4343. As far as energy is concerned, as we might expect Poland consumes higher amounts of primary energy and electricity. At the same time the respective per capita figures are lower than the Eastern EU average while similar is the picture regarding the primary energy and electricity intensity.

As a result the policies adapted in the Polish electricity sector are of significant influence not only for the country but for the region as a whole regarding the exploitation of resources, energy security and dependence, and the potential for cooperation in electricity imports and exports. Similarly controlling the emissions of air pollution in Poland has particular impact on the local environmental quality but also that of all the neighbouring countries through transboundary air pollution transfer effects [10]. Finally, since Poland is a full EU member, its performance in the abatement of the greenhouse related emissions has serious effect on the overall performance of the EU towards its commitments in regard of the Kyoto Protocol.

After this brief introductory note the paper continues with an analysis of the historical background that Eastern European countries have concerning their electricity and environmental policies throughout the last decades. In the same section the author takes the chance to make special reference to Poland but also to provide comprehensive information about the related facts for the former USSR and CEMA members. Subsequently the current state of the electricity sector in Poland is presented along with data regarding generation installations, transmission networks and used resources. Subsequently the results are discussed in the light of the time variable evolution of macroeconomic indicators. Finally, the present study concludes with useful suggestions for the effective management of the electricity sector of Poland which could be of interest to several other Eastern European countries. One may notice that not all the countries of Table 1 appear in the rest of the paper. That is particularly true for Estonia, Latvia and Lithuania as these countries used to be part of the USSR and therefore should be examined in a different context. Also Slovenia was part of the former Yugoslavia and the availability of individual data is rather limited while Slovakia and Czech Republic appear as Czechoslovakia. Finally, wherever possible the following analysis includes information about East Germany, known also as former GDR.

2. From CEMA to the EU: a historical briefing

The Eastern European countries had an initial form of common organisation in place since the early post-Second World War days of 1949 when USSR had established the Council for Mutual Economic Assistance, known also as CMEA, CEMA or COMECON, in order to co-ordinate its activities in the newly acquired areas [11]. Among the funding members were Albania, Bulgaria, Czechoslovakia, Hungary, Romania, Poland and Soviet Union. Soon after, by 1950, East Germany had joined and later Mongolia, Cuba and Vietnam became members.

From the European CEMA members, Poland was the only one with significant domestic energy resources, particularly solid fuels. The economic policy of the country included investment plans for the development of the production of solid fuels, not as a response

Table 1
Physical, economic and energy dimensions of Eastern European countries (source: Eurostat [9]).

	Bulgaria	Czech	Estonia	Hungary	Latvia	Lithuania	Poland	Romania	Slovakia	Slovenia
Population (millions)	7.756	10.221	1.348	10.098	2.306	3.452	38.174	21.659	5.385	1.998
Area (km^2 10^3)	110910	78866	45226	93030	64589	65200	312679	238392	49035	20273
Population density (capita/km^2)	69.9	129.6	29.8	108.5	35.7	52.9	122.1	90.9	109.8	98.6
GDP (B EUR1995)	12.57	54.40	5.75	51.31	7.38	9.05	160.66	33.61	22.34	22.79
GDP per capita (EUR/capita)	1621	5322	4266	5081	3200	2622	4209	1552	4149	11406
Gross energy consumption (ktoe)	19884	44795	5563	27920	4718	8592	93935	39146	19407	7305
Gross energy consumption per capita (kgoe/capita)	2562	4383	4128	2765	2046	2508	2461	1807	3604	3657
Final electricity consumption (GWh)	25678	55246	6023	32336	5701	7930	98835	39046	22850	12742
Electricity consumption per capita (kWh/capita)	3311	5405	4468	3202	2472	2297	2589	1803	4243	6377
Energy intensity (kgoe/1000 EUR)	1936	823	967	544	645	949	585	1165	869	321
Electricity intensity (GWh/B EUR)	2043	1016	1047	630	772	876	615	1162	1023	559

Table 2
Ratio of electricity to primary energy consumption and electricity dependence of Eastern European Countries in 1985.

Country	Electricity/primary energy (%)	Imported electricity (%)
Bulgaria	4	27
Czechoslovakia	1	20
East Germany	2	8
Hungary	2	32
Poland	~0	~0
Romania	2	~0

to the world oil shortages but as an opportunity to increase earnings in hard currency. Nevertheless, the investments were associated with large scale loans from the West which together with a series of other reasons (ineffective investments in other economic sectors, high infrastructural investments, and fast increase in consumption that was disproportionate to the increase in labour productivity) put Poland in debt for many years to come [12]. Therefore despite the country's plans to become a European leader in the production of solid fuels and double the extraction of brown coal and lignite, serious studies have been doubtful of the success of these aims [13].

Indeed the Polish People's Republic (PPR showed some progress only in the middle 80s. This lack of progress was at least in part due to the economic collapse caused by the revolt against the communist regime. The martial law that was declared in late 1981 decelerated the economic decline but in 1983 national output and living standards were still more than 20% below those of 1978 [14]. Table 2 shows in the first column, the ratio of electricity consumption to primary energy consumption. Nevertheless we see that electricity consumption in Poland in the middle 80s constituted an insignificant part of the national primary energy consumption. That was a combined result of the developed industrial sector which consumed a lot of energy and the underdeveloped domestic sector which did not consume electricity. It is noteworthy though to mention the electricity independence of Poland, which is significantly different to the status of countries like Bulgaria and Czechoslovakia that have imported, respectively, 27% and 20% of their electricity. Hungary has been completely dependent on external sources for its electricity, mostly to Ukraine [8]. Finally, one may not disregard that apart from electricity, East European countries have been largely depended on Russian natural gas and oil [15], something which is today valid for the whole EU, raising questions of energy security.

The political reform of the late 80s resulted in the overthrown of the communist regime and the establishment of elected governments. The 1989–1992 period was characterised by instability in most East European countries as they moved from centralised to liberal governance. The electricity sector has not remained untouched as is clear from Table 3; all examined countries presented significant electricity consumption reductions varying from 16% for Poland and Hungary to 31% for Romania. The economic instability and uncertainty in electricity market was at the same time reflected in an increase in electricity intensity which was relatively low for Romania, Poland and Hungary (3%, 3%, and 4%, respectively) but of rather important size for Bulgaria and Czechoslovakia (19% and 13%, respectively) [16]. Results for the former GDR are not presented in Table 2 because GDR at 1992 was already a region of Germany and no individual data were available. At this point it would be of help to mention that any rise at the energy intensity of Eastern European countries was additional to an already high energy intensity that characterised not only the CEMA but also the former USSR world. More specifically it has been shown that if the energy intensity of USSR in 1985 was similar to the Western European average energy consumption in USSR would have been one third lower than it actually was. That situation was a consequence of organisational rather than technical problems as the energy prices of USSR have not followed the rising worldwide trends, hence the motivation for energy-efficiency investments was missing [17].

Table 3
Changes in electricity consumption and intensity during 1989–1992.

Country	% gross electricity consumption	% electricity intensity
Bulgaria	−24	19
Czechoslovakia	−13	13
Hungary	−16	4
Poland	−16	3
Romania	−31	3

Finally, it is important to mention that while the gap between the energy intensity of transitional and Western countries has often been considered as a signal of the former's energy inefficiency, in theory this is not always correct. Various socio-economic and environmental parameters may be responsible for setting the framework where both energy efficiency and energy intensity are formed and their direct comparison does not correct lack of extensive data for different circumstances. Regardless these comments, the wide gap between the energy intensity of transitional and Western countries underlines vividly not only potentially different circumstances but also remarkable inefficiencies of the former [18].

The beginning of the 90s found Poland in a rapidly changing environment, with energy demand in the industrial sector in contrast to that of the household sector. The first was suddenly exposed to free markets and competition that had to be faced without public subsidies, while additional pressure was imposed by the collapse of exports to the former CEMA and USSR countries. Demand in the latter increased due to the growing reliance on electrical appliances but also to the increase in average property size which occurred both in the urban and rural households [19]. In fact, Poland was the country that achieved the best results within EU-10, in controlling its energy intensity [20]. There is no doubt that this has been a result of several factors. First and probably most was the momentum towards privatisation in Poland in the face of various difficulties [21]. Additionally, new firms have been successful in responding to the increased energy prices and managed to improve significantly their efficiency leaving behind public sector traditions [22,23]. Finally, the Polish primary energy fuel exhibited gradual change; coal became less important while oil, natural gas, CHP and renewable energy sources moved up the agenda [24].

Since it is a common observation that the gap between the energy efficiency of the EU-15 and the Eastern European countries has been and still is relatively high one may consider it useful to specify the exact reasons that have contributed in that trend. In an attempt to identify these reasons it would be sensible to examine the background of these countries or in other words, their starting points. As has been mentioned before the EU-15 members had gained significant ground improving energy-efficiency indicators at the time Eastern European countries were just starting related efforts.

3. The Polish electricity sector

The electricity generation of Poland is based on 15 large (installed capacity higher than 700 MW) power plants and double as much heat and power cogeneration (CHP) plants, most of which are state owned. Additionally the sector has 25 medium sized (installed capacity lower than 700 MW and higher than 100 MW) power stations spread throughout the country. In Fig. 1 [25] one may observe the constant increasing trend of the installed

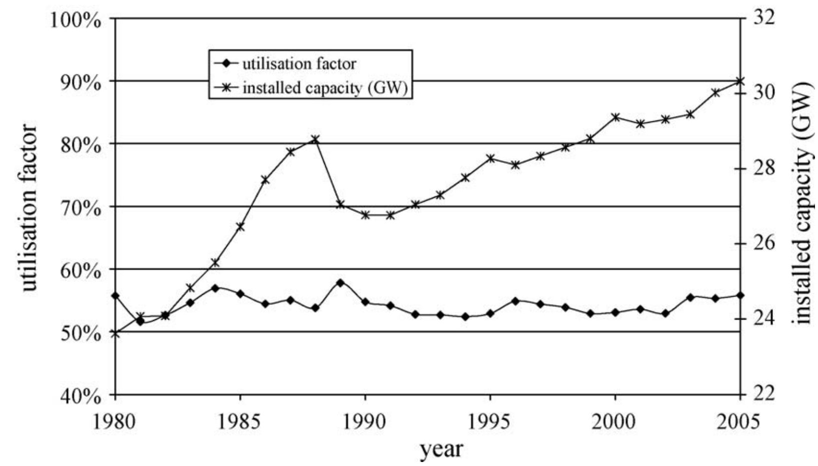


Fig. 1. Time evolution of the utilisation factor and installed capacity in Poland (source: EIA [25]).

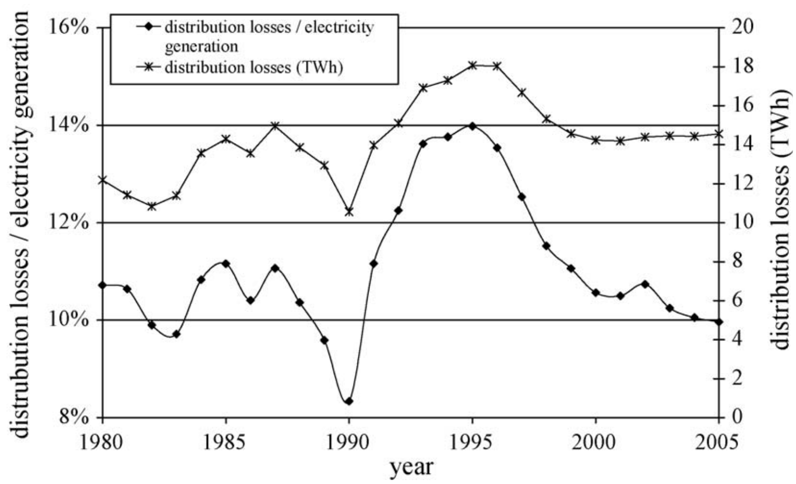


Fig. 2. Time evolution of the ratio of distribution losses per electricity generation and distribution losses in Poland (source: EIA [25]).

electricity generation capacity of Poland which over the course of the 25 years studied increased by approximately 25%. While the first peak of the curve appears in 1988 with 29 GW, the shutdown of several installations during the transitional period and the constant but slow recovery that followed, 1988 levels were reached again only after 2000, and finally exceeded 30 GW by 2005. An alternative useful measure is the evolution of the utilisation factor which is the ratio of actual electricity generation from installations to the hypothetical electricity that could be generated if the installations had been in operation 24 h/day, 360 days/year. Throughout the whole study period there are no significant changes in the utilisation factor which for the electricity installations of Poland; it has taken values between 52% and 58%. While there are several parameters that can influence the utilisation factor (also known and as load factor) it is worthwhile mentioning the age and reliability of the installations where young age and high reliability raise the load factor. Subsequently the load factor is found to be lower in countries with wide seasonal variation of electricity demand, since the usually applied strategy is the increase of the installed capacity that is only used to cover rare peak loads.

Electricity transmission at high voltage is provided by a single state controlled entity known as the Polish Power Grid Company and 33 regional retail distributors [26]. As regards to the transmission network of Poland, this has undergone significant improvements in the last years. However, the distribution losses remain relatively high and as one may notice in Fig. 2, vary between 12 and 18 TWh on an annual basis. What is more interesting though is the comparison of the distribution losses curve with the distribution loss per electricity generation ratio curve. The latter varies between approximately 13% and 17% following the trends of the former curve. Interestingly though after 1998 the distribution losses stabilised while the distribution loss to electricity generation ratio followed a declining trend, falling to 10%. That can be explained by the fact that total electricity generation in Poland was increasing and at the same time the improved technical infrastructures have allowed for the stabilization of the distribution losses.

As it becomes obvious from Fig. 3a–c [9] Poland bases its electricity generation on solid fuels primarily coal and lignite. The latter contributed in 2005 to electricity generation at a rate higher than 38%. The four largest lignite mines produce almost 60 million kton of fuel which is used as fuel for electricity generation. Despite the vast domestic reserves of lignite in Poland, its contribution to the electricity fuel mix of the country has remained relatively stable throughout the whole first transitional decade, not exceeding significantly 50 TWh/annum [27]. Other fossil fuels like natural gas and oil are only marginally used for

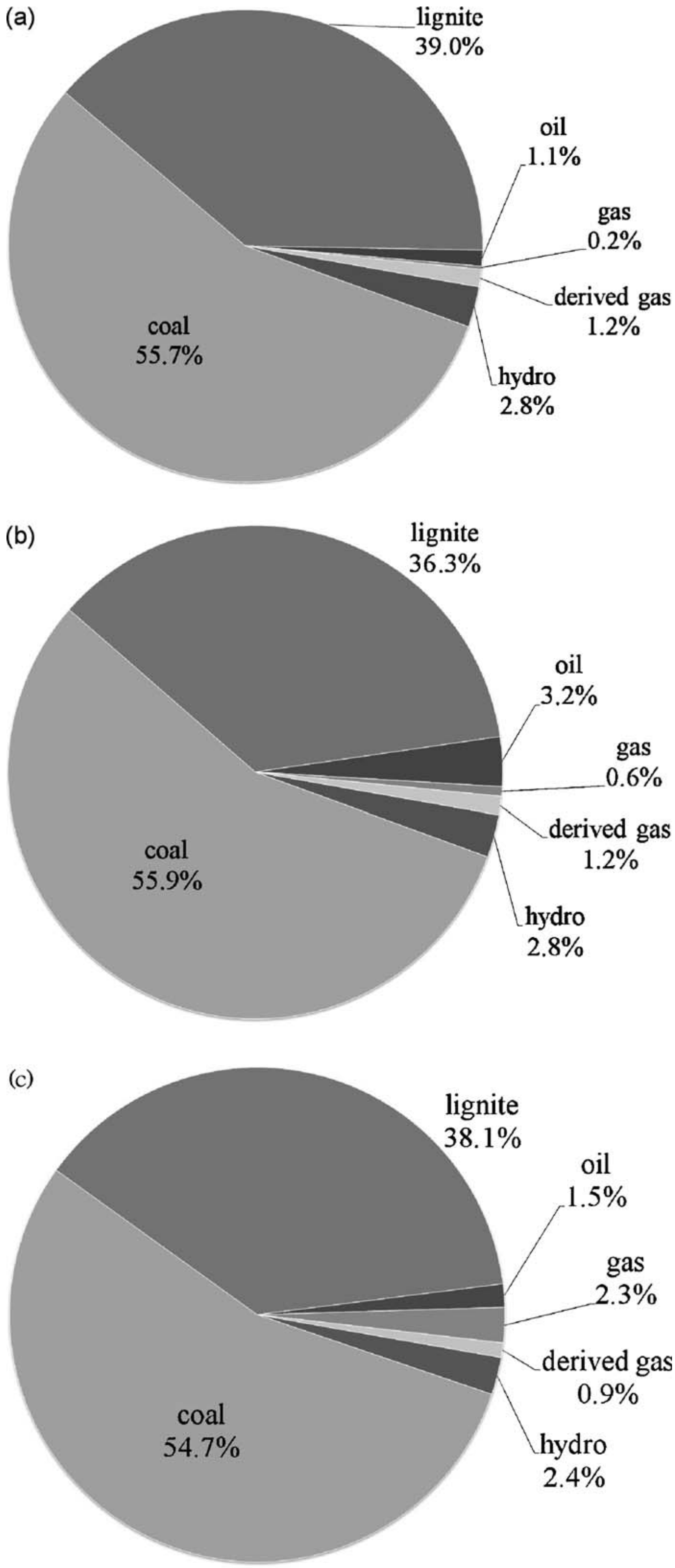


Fig. 3. (a) Electricity generation fuel mix in Poland by 1995 (source: Eurostat [9]). (b) Electricity generation fuel mix in Poland by 2000 (source: Eurostat [9]). (c) Electricity generation fuel mix in Poland by 2005 (source: Eurostat [9]).

electricity generation in Poland. Also the penetration of renewable energy sources is low but is expected to grow in response to EU Directive 2001/77. However, the EU target of 7.5% renewable-based electricity by 2010 in Poland should not be considered easy to achieve [28]. Finally, the Polish nuclear sector has many times been designed and announced but never realised. Already in the mid-1980s there were plans for installing four VVER-440 at Zarnowiec area and two VVER-1000 PWR reactors at Kujawy. However, the plans were postponed until the 1990s when eventually the transition was yet one more obstacle for their implementation [8]. Latest announcements suggest that Poland will cooperate with Lithuania in order to build a nuclear power plant on land of the latter [29]. Finally, observing the changes over time of the fuel mix used at the electricity sector of Poland it is easy to understand that they are marginal. Solid fuels lignite and hard coal keep a share of more than 92% throughout the whole period examined.

4. Discussion of the results

Electricity generation in Poland increased constantly since the beginning of 90s. In Fig. 4 one may notice the time evolution of the electricity generation per capita in Poland in the period 1980–2005. The first peak occurred in 1987 just before the transitional period when electricity generation per capita reached 3.6 MWh annually. Until 1992 the respective figure fell to 3.2 MWh/annum and only a decade later, in 2003 electricity generation per capita once again reached the levels of 1987.

While per capita electricity generation in Poland has been in an increasing trend since 1992, radically opposite is the situation with regard to electricity intensity (Fig. 5) [25,30]. The latter followed an acute decline and by 2006 had reached almost 250 Wh/US$ of GDP produced (2006 prices). Prior to transition the lowest (as shown in Fig. 5) energy intensity figure recorded in 1980 was approximately 325 Wh/US$, an amount that after the increasing trend of the 80s has only been reached again in 1997. The increasing trend recorded prior to 1992 is related to a number of reasons but mostly to the delayed response of the industrial sector to the transitional needs. Large inefficient industries did not shut down for a few years but either kept their low value-added production stable or reduced it to even less efficient levels which as a result kept electricity consumption high however, reduced the GDP [31]. Reduced electricity intensity in Poland after 1992 was partially a result of an improved management and rationalization of the domestic industrial activities. Particularly inefficient heavy industries of the communistic era gradually declined and gave place to higher value-added and less energy intensive industries [32]. It is noteworthy to mention that the GDP used for Fig. 5 is the Purchasing Power Parity which takes into account differences in the relative prices of goods and services – particularly non-tradables – and therefore provides a better overall measure of the real value of output produced by an economy compared to other economies [33].

When studying Figs. 4 and 5 one may not disregard the fact that although the privatization process in the electricity industry has theoretically started, in reality only minor number of power plants had passed out of the control of the state or to local authorities. Additionally, the only power plants that are private were existing plants that were privatised. In other words no new private investments were made in the polish electricity sector except for the renovation of existing installations. However, the situation with regard to electricity retailing is significantly better. Billing is already based on the consumption of individual consumers and some steps have been taken to improve public awareness for energy efficiency [20,34]. That being said, the expectations for further improvements with respect to the operation of the electricity market are high, especially given the market-based environmental regulations that are gradually taking effect.

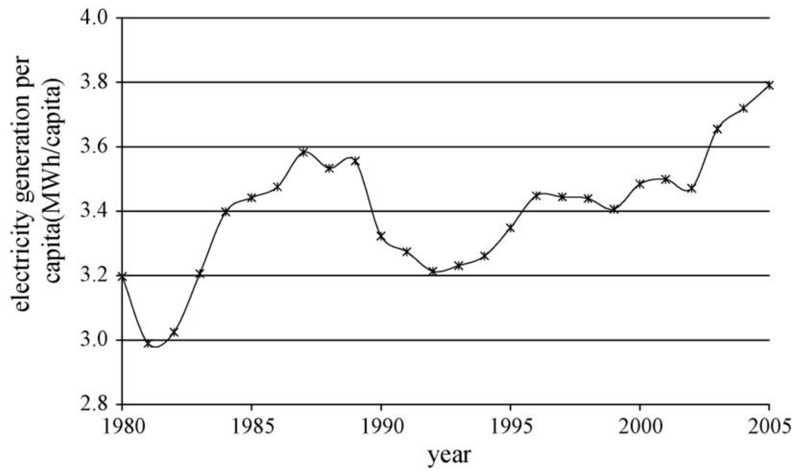


Fig. 4. Time evolution of the electricity generation per capita in Poland (source: EIA [25]).

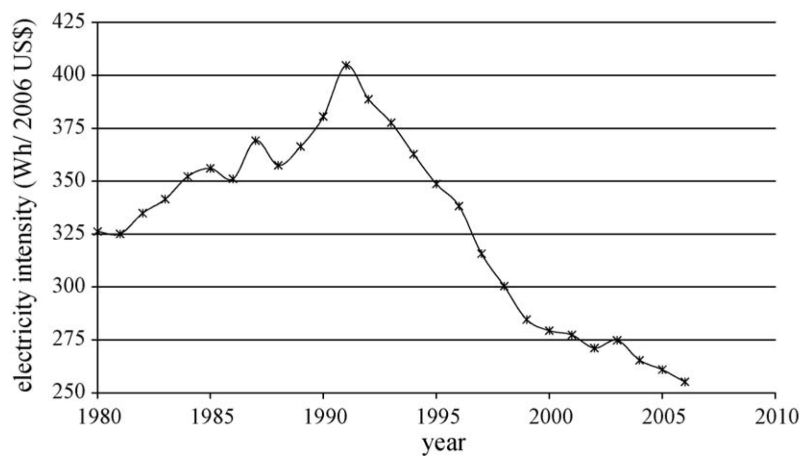


Fig. 5. Time evolution of the electricity intensity in Poland (source: EIA, The Conference Board and GGDC [25,30]).

5. Conclusions

In this paper the historical background concerning the energy and electricity policies of Eastern Europe has been examined. While primary focus is placed on Poland this is placed in the context of Eastern European former CEMA and USSR countries. The subsequent analysis allows for an improved understanding of certain parameters of the Polish electricity sector through the study of the time variability of indicators such as the load factor and transmission losses to total generation ratio. Finally, an examination of the electricity market characteristics takes place with regard to electricity intensity and per capita generation time evolution.

The study presented serves as a reference overview of the current electricity market of Poland but mostly provides the background framework that explains the historical and political circumstances that led in the present status. As the second period of the emissions trade has already started the electricity sector of Poland will have to face certain economic and political challenges [35]. Addressing the latter appropriately not only will be essential for the integrity of the sector but might reveal the potential for significant benefits both at the domestic economics – through emission allowance savings – and the social welfare [26]. Finally, any attempt to examine the Polish electricity sector must consider the fact that Poland has always been energy independent, using domestic solid fuels. Contemporary environmental agenda underline the need for a shift of electricity resources to less carbon intensive ones such as natural gas, nuclear and renewable energy. While the latter can be exploited domestically the two former can only be imported, a strategy that would undermine the electricity supply security that Poland has enjoyed in the last decades. Particularly with natural gas the dilemma is inevitable as the Russian Federation which can be considered as a major supplier has been involved in the past in bilateral trade conflicts with Poland [36] and natural gas supply conflicts with Belarus [37] and Ukraine [38].

Further opportunities of financial nature are available mostly in the EU context and any investment plans should not underestimate their importance especially for the new EU members. That being said the European Union structural funds allocation mechanism in Poland has not been designed with renewable energy projects in mind and therefore significant improvements are expected at its new forms [39]. At the same time given successful control of GHG, electricity utilities may be benefited financially from selling carbon allowances that they have not used.

Finally, the author believes that extensive research is needed in order to identify the national and sectoral paths that will allow the new EU member states to develop their economics in a sustainable way. Particularly for Poland it is necessary to identify how the coal-based electricity sector will improve its environmental performance

or be substituted by less carbon intensive fuels without threatening the social coherence. At a bottom-up approach extensive study will allow improved understanding of the strategic change management that electricity utilities need to adopt in order to response in an efficient manner to the current and forthcoming air pollution and climate change related regulations. While the electricity sector is not the only one creating environmental hazards, its proper regulation has large improvement potential and will be a key element for further optimization in other sectors that depend on electricity consumption.

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